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(54) Title of the invention: Etching Method for Aluminum Foil

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Specification

1. Title of the invention: Etching method for aluminum foil

2. Scope of patent claims:

(1) An etching method for aluminum foil characterized by conducting etching treatment after providing numerous corrosion-resistant fine lines on the aluminum foil surface.

(2) An etching method for aluminum foil according to Scope of patent claim 1 characterized by providing the fine lines in parallel in the rolling direction of the aluminum foil.

(3) An etching method for aluminum foil according to Scope of patent claim 1 characterized by providing the fine lines in slanted form in the rolling direction of the aluminum foil.

(4) An etching method for aluminum foil according to Scope of patent claims 1, 2, or 3 characterized by providing the fine lines on one side of the aluminum foil.

(5) An etching method for aluminum foil according to Scope of patent claims 1, 2, or 3 characterized by providing the fine lines on both sides of the aluminum foil.

3. Detailed explanation of the invention:

This patent application relates to an etching method for aluminum foil that seeks to obtain etching foil that has superior tensile strength and bending strength, and that can avoid damage such as cutting in the winding process of the capacitor element.

As is generally known, aluminum foil that is used in the electrodes of electrolytic capacitors undergoes etching treatment that corrodes the surface in order to increase the effective surface gain.

After conducting etching treatment, however, the mechanical strength such as tensile strength and bending strength of the aluminum foil is reduced by the corrosion. Consequently, in cases where the capacitor element undergoes winding by an automatic winder or the like, there occur troublesome problems such as cutting or the like in the attachment part or wind core part of the terminal. Etching method researchers are currently struggling with regard to how to obtain a large effective surface gain without impairing the mechanical strength of the aluminum foil.

In light of this point, the inventor of the current patent application has done research and succeeded in creating an etching method that easily obtains aluminum foil with superior mechanical strength without reducing effective surface gain, and herein presents the etching method. Its is characterized by

conducting etching treatment after providing numerous corrosion-resistant fine lines on the aluminum foil surface.

That is, numerous fine lines that resist corrosion and delay the start of erosion are provided on both the front and back face or on either one of the faces of the aluminum foil that undergoes etching treatment. By conducting the etching treatment in this state, a corroded surface is formed that has numerous deep irregularities with a large amount of melting in the parts where the fine lines are not provided, while a corroded surface is formed that has numerous shallow irregularities with hardly any melting or with a small amount of melting in the parts where the fine lines are provided, thereby obtaining etching foil that as a whole possesses superior mechanical strength without impairment of effective surface gain.

There are various methods for providing fine lines that resist corrosion. The simplest method is the printing method. As most printing inks have poor wettability relative to corrosive liquids and serve to delay the advance of corrosion, this method is very effective in implementing the invention of this patent application. In addition, there is also the method that provides oxidized fine lines by heating with laser beams, the method that provides fine lines by the pressing action of a roller, and so on. With the former method, the heat-generated oxides resist corrosion, and with the latter method, the changes in aluminum structure due to the pressure change resist corrosion. These corrosion-resistant fine lines leave high-strength parts in the foil after etching treatment just like a reinforcing foil, with the result that the aluminum foil possesses superior mechanical strength after etching.

The width, spacing and mode of arrangement of the fine lines are selected at one's discretion in relation to the setting of effective surface gain and mechanical strength. Fig. 1

shows the case where numerous fine lines (2) are provided in parallel in the lengthwise direction – that is, the rolling direction – of the aluminum foil (1). With this configuration, tensile strength in the rolling direction and bending strength in the direction orthogonal to the rolling direction are strengthened. Accordingly, as electrode foil that is wound in an ordinary capacitor element is slit cut at the required width in parallel in the rolling direction, this is a most preferable configuration for providing fine lines in the aluminum foil. Fig. 2 shows the case where numerous fine lines (2) are provided in a slanted manner in the aluminum foil (1), while Fig. 3 shows the case where numerous fine lines (2) are provided in the aluminum foil (1) so that they cross in an X-shape. These configurations also result in superior tensile strength and bending strength. Furthermore, Fig. 4 shows a configuration for the case where numerous fine lines (2) are provided in parallel in the direction orthogonal to the rolling direction. This configuration is effective in cutting the aluminum foil (1) to the required width in the direction orthogonal to the rolling direction, and obtaining electrode foil.

Fig. 5 (a) and (b) show enlarged sectional views of the aluminum foil after etching. Fig. 5 (a) shows the case where the fine lines (2) are provided on only one side of the aluminum foil (1), while Fig. 5 (b) shows the case where the fine lines (2) are provided on both sides of the aluminum foil (1).

By providing corrosion-resistant fine lines, it may at first glance appear that the effective surface gain of the aluminum foil will be reduced compared to aluminum foil obtained without providing the fine lines, but experimental results have demonstrated that hardly any difference occurs in the capacity ratio of the capacitor. The reason for this would seem to be that it is sufficient to have the proportion occupied by the fine lines amount to a small percent of the total area, and that the corrosion melt amount that is lost in the fine line parts can be offset by the

other parts without fine lines. Moreover, when the corrosion melt amount of the aluminum in the case where fine lines are provided is identical to that in the case where the fine lines are not provided, the average sectional area of the parts that remain without being corroded becomes approximately equal. Consequently, although it may appear that no difference will occur in mechanical strength, experimental results have demonstrated that a marked difference occurs in mechanical strength. The reason for this would seem to be that the corrosion of the parts where the fine lines are not provided is deep, and these parts are accordingly brittle, tear easily, and their strength per unit of sectional area is low, whereas the fine line parts are tough due to the >*shallow* corrosion, and their strength per unit of sectional area is high.

A detailed description is given in the following embodiments.

Sample 1

Annealed aluminum foil with a thickness of 100 μ and purity of 99.99% was subjected to etching treatment by the conventional electrolytic etching method in a chloride solution, and the solubility loss was controlled to be approximately 38%.

Water rinsing treatment was then conducted, after which formation occured at 375V in a boric acid solution.

Sample 2

With regard to Sample 1, before conducting the etching treatment, fine lines were provided in parallel at intervals of 2.5 mm on one side of the aluminum foil and in the rolling direction of the aluminum foil by marking ink with a width of 0.25 mm.

Sample 3

With regard to Sample 2, the fine lines were provided on both sides.

In these experimental cases, with regard to capacitance measurement, equivalent electrostatic capacity was obtained by conducting measurement by bridge in an electrolytic solution, and this value was then divided by area (cm^2), and the $\mu F/cm^2$ value was calculated. With regard to the measurement of tensile strength, etching foil cut into parallel slits of 10 cm length and 1 cm width in the rolling direction was subjected to tensile force in the rolling direction, the tensile force was increased at the rate of 0.25 kg per second to obtain the kg value at the time of rupture, which was then used to calculate the tensile strength kg/cm value. Furthermore, with regard to bending strength, samples identical to the aforementioned tensile strength measurement samples were bent at a 45° angle in the lengthwise direction with the bent surface at this time being used as the radius of curvature for 1 mm. A tensile force of 250 g was imparted in the lengthwise direction, and the sample was returned from its 45° bent state to its original state, after which it was bent at a 45° angle in the opposite direction, and again returned to its original state, which counted as 1. This procedure was repeated until obtainment of the number of times at which the bent part severed. The results are shown as follows.

Note

	Capacitance $\mu F/cm^2$	Tensile strength Kg/cm	Bending strength
The case of Sample 1	0.72	1.2	3
The case of Sample 2	0.72	1.5	10
The case of Sample 3	0.71	1.8	19

As is clear from the foregoing experimental results, according to this invention, compared to the etching foil obtained by the conventional method, the obtained mechanical strength is very high and there is remarkable improvement in bending strength in particular, despite the fact that capacitance remains approximately the same, and consequently this is clearly very advantageous for the winding operations of the capacitor element in automatic winder devices and for handling operations.

As a result of numerous experiments, as stated above, the method that provides the fine lines by printing is the simplest and most practical. With regard to the printing ink used in this case, it was learned that the full effects are obtainable with either aqueous or oil-based ink. The inventor initially considered that it would be necessary to provide the fine lines on the aluminum foil by thickly applying ink possessing very strong corrosion resistance, but experimental results have shown that the full effects are obtainable even with application of fine lines in a thin layer using ink that is very weak in corrosion resistance. The reason for this would seem to be that corrosion initially progresses in a gradual manner, and subsequently progresses rapidly, and that corrosion in the parts not provided with fine lines has terminated before corrosion has progressed in earnest in the parts provided with fine lines by ink.

4. Brief description of the drawings:

Fig. 1 through Fig. 4 are respectively partial plan views of the etching foil in the embodiments of this invention. Fig. 5 is an enlarged sectional view of the etching foil.

In the drawings, (1) indicates the aluminum foil, and (2) indicates the fine lines.

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Fig. 1

Fig. 2

Fig. 3

[see source for figures]

Fig. 4

Fig. 5

(a)

(b)